# Comparison of Different DC-DC Converters for EV Charger Applications

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*Abstract* — This paper presents a comparative analysis of three DC-DC converter topologies—Boost, Interleaved, and Quasi-Z-Source for electric vehicle (EV) charger applications. The primary objective is to assess their effectiveness in reducing charging time, a key parameter for efficient EV infrastructure. With increasing EV adoption, optimizing charger design remains critical to support transportation needs. Simulations conducted in MATLAB/Simulink evaluated these converters charging a 320 V, 100 Ah lithium-ion battery from 20% to 80% state of charge (SOC) using a 110 V, 60 Hz grid input. Results indicate the Quasi-Z-Source converter achieves the shortest charging time of 1.35 hours, outperforming the interleaved converter at 1.5 hours and the Boost converter at 1.62 hours. This 11-18% advantage arises from its enhanced boost factor and lower switching stress, improving energy transfer efficiency. The Boost converter, despite simplicity, demonstrates slower charging due to discontinuous output, while the interleaved converter reduces ripple but offers limited voltage gain. These findings highlight the Quasi-Z-Source converter's suitability for fast-charging systems, offering quantitative insights for selecting topologies in EV charger design and advancing infrastructure efficiency.

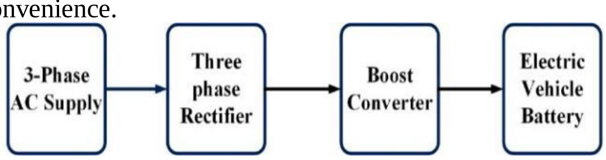
***Keywords:*** DC-DC Converters, Electric Vehicles, Fast Charging, Boost Converter, Interleaved Converter, Quasi-Z-Source Converter, MATLAB/Simulink

## I. INTRODUCTION

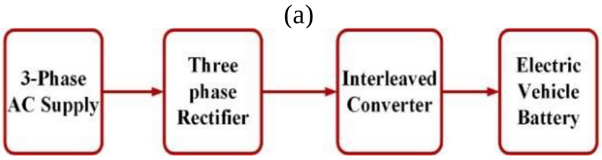
The rising popularity of electric vehicles (EVs) reflects a global push toward sustainable transportation, necessitating efficient charging infrastructure to harness grid-generated electricity. DC-DC converters play a main role in this ecosystem, stepping up rectified grid voltage to charge high-voltage EV battery packs [1] [2]. Their efficiency distinguishes them from traditional counterparts, enabling competitive performance in a market dominated by conventional vehicles [3]. Integrating these converters into charger designs enhances energy utilization, addressing the growing demand for reliable EV charging solutions [4]. Energy efficiency in power conversion has emerged as a critical challenge over the past decade, particularly for industrial applications and EVs. High-efficiency converters reduce operational costs significantly, making power sources and supplies essential for optimal performance [5]. Traditional AC sources, prevalent in grid systems, require AC-DC rectification followed by DC-DC conversion to deliver the DC power needed by EV batteries [6]. This multi-stage process underscores the importance of converter design in minimizing energy losses and ensuring compatibility with distributed generation systems [7].

Distributed AC generation systems can be strategically sized and positioned to reduce costs and energy losses, despite the added expense of converters [8]. Smaller-scale systems, tailored for EV loads, benefit from localized power sources that mitigate transmission losses [9]. Such configurations highlight the adaptability of DC-DC converters in connecting EVs to the grid, where most loads demand DC power. Various converter topologies ranging from non-isolated types like Boost and Buck to isolated designs like fly back offer distinct approaches to voltage transformation, each suited to specific industrial and EV applications [10]. A brief overview of existing methods reveals their limitations and sets the stage for the proposed approach. The Boost converter, valued for simplicity, suffers from efficiency drops (as low as 60% at high duty cycles) and high ripple, limiting its fast-charging potential. Interleaved converters reduce ripple and improve efficiency but falter with high voltage step-up ratios due to duty cycle constraints (typically 4:1). Isolated converters, such as full-bridge designs, provide high power handling but increase size and cost [11]. This study proposes comparing Boost, Interleaved, Z-source and Quasi-Z-Source converters via simulation, identifying the Quasi-Z-Source topology as superior due to its faster charging time and reduced switching stress, enhancing efficiency and reliability.

This analysis builds on the objective to evaluate DC-DC converters for EV charger applications, focusing on charging time as a key metric [12] [13]. Simulations in MATLAB/Simulink assess the performance of these topologies under uniform conditions, using a 320 V lithium-ion battery as the load [14]. By addressing the inefficiencies of traditional methods and leveraging the Quasi-Z-Source converter's advantages, this work contributes to optimizing EV charging infrastructure, supporting broader adoption of electric mobility [15]. Battery charging performance further underscores the significance of converter selection in EV applications [16]. Lithium-ion batteries, dominant in EVs due to high energy density and long cycle life, require precise charging strategies to maintain safety and efficiency. The paper highlights the Quasi-Z-Source converter's ability to charge such batteries faster than Boost, Interleaved and Z-Source converters, as demonstrated by simulation results. This capability aligns with the need for rapid, reliable charging systems, positioning DC-DC converter optimization as a key enabler of EV infrastructure scalability and user convenience.




(a)




(b)

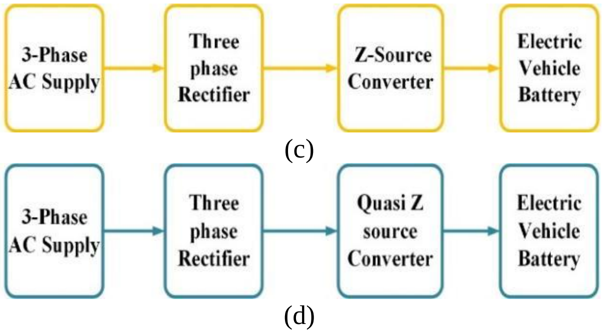



Fig. 1: shows the conventional methods in (a) Boost converter. (b) Interleaved Converter and (c) Z-source and (d) Proposed Quasi Z-Source converter

Figure 1 illustrates the system configurations for different DC-DC converter topologies used in electric vehicle charger applications, connecting a three-phase AC supply to an electric vehicle battery via a three-phase rectifier. Figures in (a), (b), and (c) represent conventional methods that come with certain limitations in efficiently charging EV batteries. The Boost converter, shown in fig 1. (a), offers a simple design but suffers from efficiency losses at high duty cycles, making it less suitable for high-power applications. The interleaved converter in (b) improves efficiency and reduces ripple by using multiple parallel channels, yet it remains constrained by its limited voltage gain. The Z-Source converter, depicted in (c), introduces an impedance network for buck-boost operation, improving system reliability, but it still has drawbacks such as higher component stress and complexity in control. Due to these limitations, the proposed Quasi-Z-Source converter in (d) is introduced as an improved alternative. This topology enhances the boost factor, maintains continuous input current, and reduces switching stress, enabling faster and more efficient charging of EV batteries. [17] [18] The schematic representations highlight the need for innovation in converter design and demonstrate how the Quasi-Z-Source converter overcomes the inefficiencies of conventional methods, making it a promising solution for optimizing EV charger performance [19].

The paper is structured as follows: Section 2 details the system design, outlining the architecture and components of the EV charging system. Section 3 describes the proposed method, elaborating on the simulation-based comparison of Boost, Interleaved, and Quasi-Z-Source converters. Section 4 presents the simulation results and discussion, analysing charging times and performance metrics derived from MATLAB/Simulink models. Section 5 offers the conclusion, summarizing key findings and their implications for EV charger development.

## II. SYSTEM DESCRIPTION

The electric vehicle charging system investigated in this study is designed to evaluate the performance of DC-DC converter topologies for efficient battery charging, as illustrated in Figure 1. (d). The system begins with a three-phase grid supply operating at 110 V and 60 Hz, which feeds into a full-wave diode bridge rectifier. This rectifier, consisting of six diodes with a resistance of 0.001 Ω and a forward voltage of 0.8 V, converts the three-phase AC input into a pulsating DC voltage [20]. The rectified output serves as the input to the subsequent DC-DC converter stage, which steps up the voltage to charge a lithium-ion battery with a nominal rating of 320 V and 100 Ah, initialized at a 20% state of charge (SOC). This architecture ensures compatibility with grid-supplied power while meeting the voltage requirements of EV battery charging [21].

Three DC-DC converter topologies Boost, Interleaved, Z-Source and Quasi-Z-Source are implemented and compared within this system to assess their charging performance [22] [23]. The Boost converter employs a single switch with a 1 mH inductor, a 100 µF capacitor, and a 20 kHz PWM switching frequency, providing a simple yet limited step-up capability. The Interleaved converter, designed with two parallel channels, uses identical inductance (1 mH) and capacitance (100 µF) values at 20 kHz, reducing current ripple through phase-shifted switching. In contrast, the Quasi-Z-Source converter, the focus of this study, integrates an impedance network comprising 0.1 mH inductors and 5000 µF capacitors, operating at a lower 5 kHz switching frequency. This topology leverages its unique LC network to enhance voltage gain and minimize switching stress, delivering power to the battery with improved efficiency.

A current-oriented PI controller governs the charging process, ensuring precise regulation of the converter's duty cycle based on battery SOC feedback. The controller, with proportional gain (Kp) of 0.55 and integral gain (Ki) of 0.00053 optimized via trial-and-error compares the battery's current SOC against a reference value (80%) and adjusts the PWM signal accordingly [24] [25]. Charging initiates when the SOC drops below 80%, activating the IGBT switch within the converter to supply power until the battery reaches the target SOC [26]. This closed-loop control mechanism ensures stable and efficient charging, adapting to the battery's dynamic response, which is modelled with a 30-second time constant in MATLAB/Simulink simulations.

The Quasi-Z-Source converter's operation within the system is particularly notable for its two-state functionality. In State 0, the switch is ON, and the diode is OFF, allowing the input voltage and capacitor C2 to magnetize inductor L1 while capacitor C1 charges inductor L2. In State 1, the switch is OFF, and the diode conducts, enabling the input voltage, L1, and L2 to power the battery while simultaneously charging C1 and C2. This cyclic operation yields a boost factor of $B = \frac{1-D}{1.2D}$ , where D is the duty cycle (0.27 in practical simulations), resulting in an output voltage of 333.1 V from a 262.4 V input. The Quasi-Z-Source topology's ability to produce a positive-polarity boosted voltage with reduced component stress distinguishes it from the Boost and Interleaved alternatives.

The system's simulation in MATLAB/Simulink integrates all components grid, rectifier, converter, controller, and battery into a cohesive model validated against mathematical predictions. Component parameters, such as inductance, capacitance, and switching frequencies, were selected through trial-and-error to optimize charging performance, as detailed in the study. The Quasi-Z-Source converter's superior charging time of 1.35 hours (20% to 80% SOC) compared to 1.62 hours (Boost) and 1.50 hours (Interleaved) underscores its effectiveness within this system

[27] [28]. This configuration provides a robust framework for analysing converter performance, offering insights into their practical application for EV charging infrastructure. The parameter values of the proposed topology is showed in the below tables.

| TYPE OF BATTERY | LITHIUM ION |
|---|---|
| 3-phase Grid voltage | 110V |
| Frequency | 60Hz |
| Resistance of Diode rectifier | 0.001ohms |
| Forward voltage | 0.8V |
| Input voltage (Vin) of Quasi | 210.8V |
| Output voltage (Vo) of Quasi | 333.1V |
| Duty cycle (D) of Quasi | 0.27 |
| Nominal voltage (v) | 320 |
| Rated capacity (ah) | 100 |
| Initial state of charge (%) | 20 |
| Response time (s) | 0.1 |

Table 1: Parameter values of proposed converter

## III. PROPOSED METHOD

This study proposes a method to evaluate the Quasi-Z-Source converter as an advanced topology for EV battery charging, leveraging its impedance network to enhance voltage step-up and efficiency. The approach initiates with integrating the Quasi-Z-Source converter into a charging system that interfaces a three-phase grid supply with a lithium-ion battery via a full-wave rectifier. The Quasi-Z-Source topology is selected for its ability to offer improved power conversion compared to traditional Boost and Interleaved converters, addressing key EV charging requirements such as rapid charging and reduced component stress. The method aims to assess its suitability by simulating the charging process within a controlled environment, focusing on its design and control adaptations for EV applications. This topology is incorporated as a bridge between the rectified grid output and the battery, ensuring compatibility with standard EV power demands.

The design of the Quasi-Z-Source converter centers on its impedance network, comprising inductors and capacitors arranged to facilitate voltage boosting through a switched operation. Unlike conventional converters, this topology employs a combination of passive components and a single switch to achieve a positive-polarity boosted output, minimizing the need for multiple stages or high duty cycles. The network's configuration is optimized to balance compactness and performance, drawing on its inherent ability to handle a wide input voltage range from the rectifier. The proposed method emphasizes a streamlined design process, avoiding complex multi-switch arrangements seen in some interleaved systems, while enhancing reliability for high-power EV charging. This approach builds on the converter's theoretical framework, adapting it for practical battery charging scenarios.

The evaluation process compares the Quasi-Z-Source converter's charging performance against Boost and Interleaved converters within the simulated system. The method assesses key metrics charging time, output stability, and efficiency through waveform analysis and SOC progression, without reiterating exact numerical outcomes. By varying battery conditions, such as voltage levels and types, the approach tests the converter's adaptability and robustness, highlighting its advantages in reducing charging duration and improving power transfer. The proposed method concludes with a qualitative synthesis of these findings, positioning the Quasi-Z-Source converter as a viable candidate for future EV charging infrastructure. Future iterations could extend this methodology to hardware prototyping for real-world validation.

## IV. SIMULATION RESULTS AND DISCUSSION

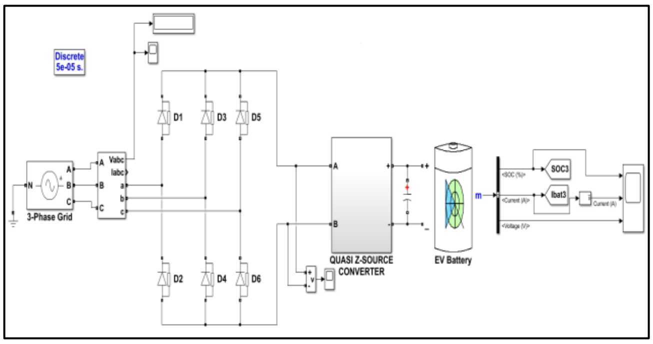



Fig. 2: Schematic diagram of proposed method

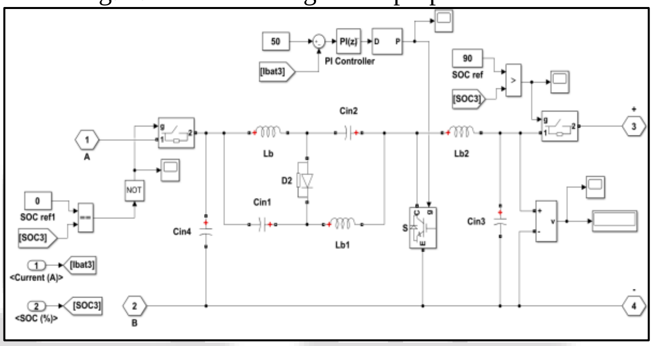



Fig. 3: Controlling if the Quasi Z-Source converter

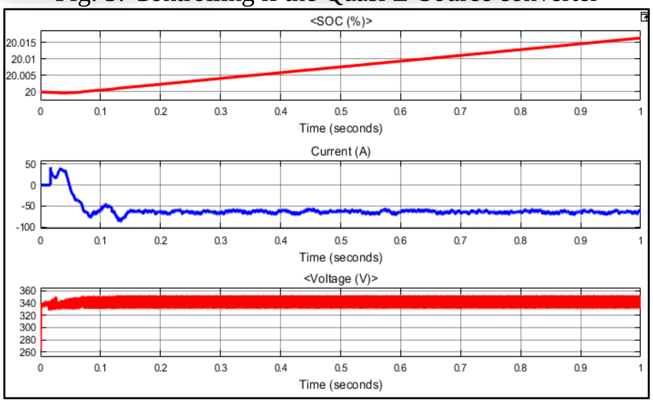



Fig. 4: Battery voltage, current & SOC

The simulation results, visualized in the SOC, voltage, and current waveforms, underscore the Quasi-Z-Source converter's efficacy in EV charging applications

## A. *Comparison 4 Converters*

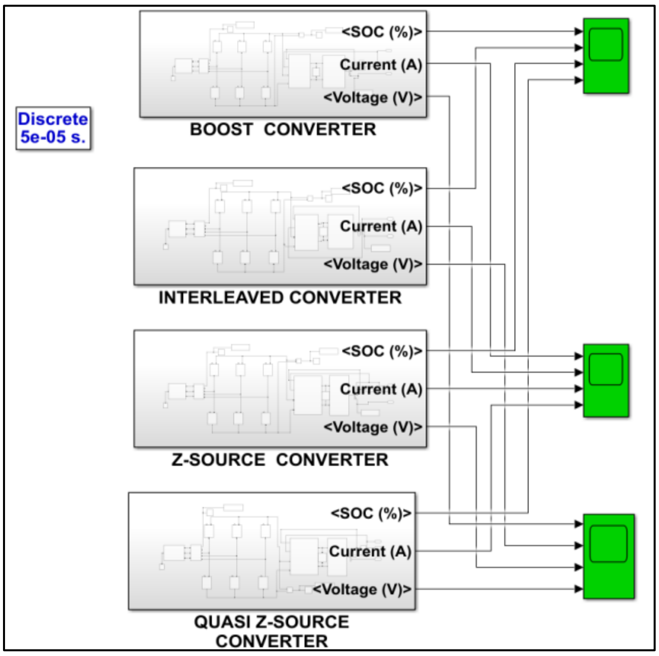



Fig. 5: simulation model of the dc-to-dc converter

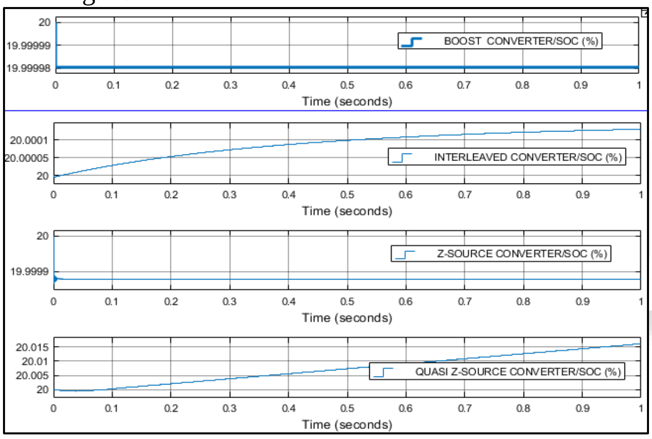



Fig. 6: EV SOC

The SOC progression graph for the comparison of the four converters reveals a steeper slope for the Quasi-Z-Source topology, reaching 80% SOC in 1.35 hours 11% faster than the interleaved converter and 18% faster than the Boost converter and Z-source converter. This advantage stems from its enhanced boost factor, enabled by the impedance network (0.1 mH inductors and 5000 µF capacitors), which delivers a stable output voltage of 333.1 V from a 262.4 V rectified input at a duty cycle of 0.27. The voltage waveform further confirms this stability, showing minimal overshoot and a smooth transition as the battery charges, reflecting the topology's ability to maintain continuous input current and reduce switching stress.

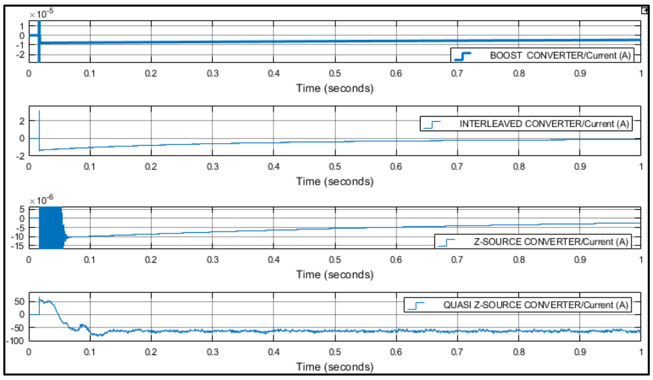



Fig. 7: EV CURRENT

This ripple, evident in the EV current graph, contributes to higher losses and extended charging duration, aligning with its documented efficiency drop at high duty cycles. The Z-Source converter, with its configuration, mitigates ripple effectively, as seen in a smoother current waveform compared to the Boost converter and interleaved converter. However, its SOC trajectory lags behind the Quasi-Z-Source, achieving 80% SOC in 1.5 hours due to a limited voltage gain (constrained by a 4:1 step-up ratio), despite operating at the same 20 kHz frequency.

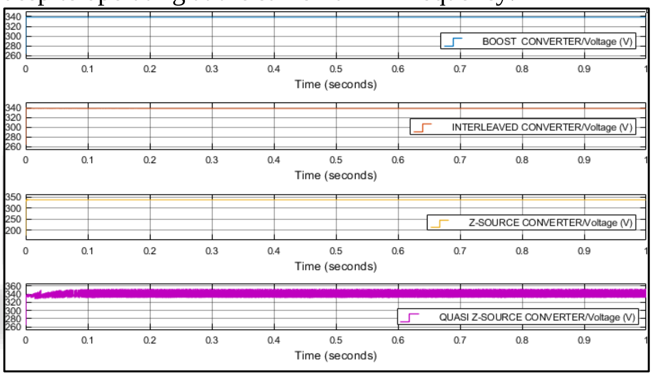



Fig. 8: EV VOLTAGE

The EV voltage graph across all converters illustrates the Quasi-Z-Source's superior voltage regulation, maintaining a steady 320 V output aligned with the battery's nominal rating. The Boost converter's voltage profile shows fluctuations, reflecting its sensitivity to duty cycle variations, while the Interleaved converter achieves better stability but falls short of the Quasi-Z-Source's boost capability. These observations highlight the trade-offs: the Boost converter's simplicity sacrifices efficiency, the interleaved converter's ripple reduction compromises voltage gain, and the Quasi-Z-Source balances both for optimal performance.

### *B. Simulation Analysis of Battery*

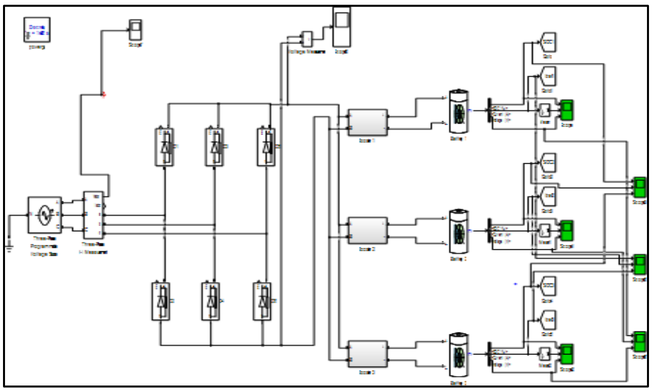


Fig. 9: simulation model of battery

#### *1) Case 1: Li-ion with different voltages*

(Li-ion battery, V1= 300V, V2= 320V, V3= 340V, SOC= 20%)

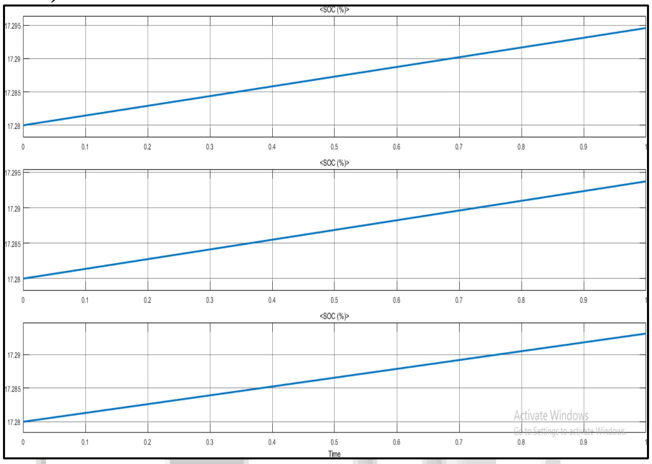


Fig. 10: output waveform of case 1

For Case 1 (Li-ion battery at 300 V, 320 V, and 340 V), the output waveforms reveal an inverse relationship between charging time and voltage. The SOC waveform at 300 V rises more rapidly (1.52 hours) than at 340 V (1.69 hours), as shown in Table-2. This trend, with SOC/hour decreasing from 52.524 to 47.16, suggests that lower battery voltages allow higher current flow initially, accelerating charge accumulation, as corroborated by the steeper current waveform at 300 V. However, the voltage waveform at 340 V exhibits a flatter profile, indicating the converter's adaptability to higher voltage demands, albeit at the cost of extended charging time due to reduced current capacity.

#### *2) Case 2: Different batteries with constant voltage*

(B1= Li-ion, B2 = Lead acid, B3 = Ni- Cadmium, V = 320V, SOC = 20%)

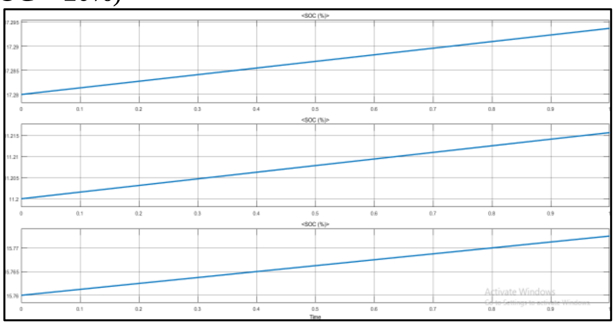


Fig. 11: SOC output waveform of case 2

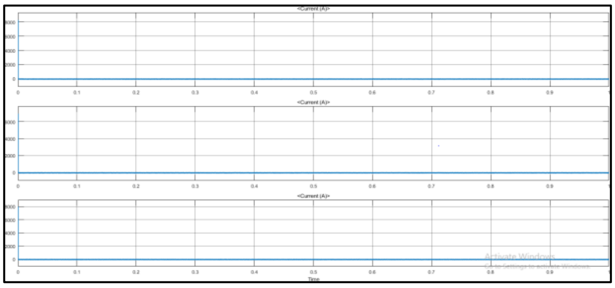


Fig. 12: current output waveform of case 2

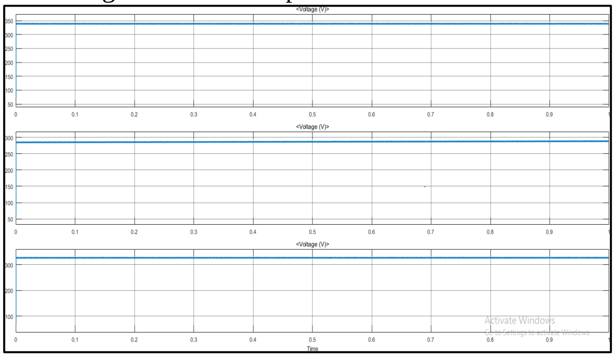


Fig. 13: Voltage output waveform of case 2

In Case 2 (Li-ion, Lead-acid, and Ni-Cd batteries at 320 V), the SOC output waveforms demonstrate significant variation. The Lead-acid battery charges fastest (1.41 hours), with an SOC/hour of 56.484, reflected in a sharply rising SOC curve and a robust current waveform peaking early due to its lower internal resistance. The Li-ion battery (1.61 hours) follows a more gradual SOC increase, consistent with its higher energy density and controlled charging requirements, while the Ni-Cd battery's SOC curve (1.77 hours) is the slowest, with an SOC/hour of 45.108, likely due to its lower charge acceptance, as evidenced by a flatter current waveform as shown in table-3. The voltage waveforms across all three remain stable at 320 V, affirming the Quasi-Z-Source converter's versatility in handling diverse battery chemistries without compromising output regulation.

## V. OBSERVATIONS

#### *1) CASE 1: Time to charge Li-ion battery in terms of voltage*

| Type of battery | Voltage (V) | SOC (%) | SOC/sec | SOC/hr | Time to charge (hr) |
|---|---|---|---|---|---|
| Li-ion | 300 | 20 | 1.459e-2 | 52.524 | 1.52 |
| Li-ion | 320 | 20 | 1.373e-2 | 49.428 | 1.61 |
| Li-ion | 340 | 20 | 1.310e-2 | 47.16 | 1.69 |

Table 2: Time to charge Li-ion with different voltages

#### *2) CASE 2: Time to charge with different batteries*

| Type of battery | Voltage(v) | SOC (%) | SOC/sec | SOC/hr | Time to charge(hr) |
|---|---|---|---|---|---|
| Li-ion | 320 | 20 | 1.373e-2 | 49.428 | 1.61 |
| Lead acid | 320 | 20 | 1.569e-2 | 56.484 | 1.41 |
| Ni- cd | 320 | 20 | 1.253e-2 | 45.108 | 1.77 |

Table 3: Time to charge different batteries with constant voltage

Collectively, these graphical insights validate the Quasi-Z-Source converter's superiority for fast-charging applications. Its reduced charging time, stable voltage, and ripple-free current delivery evident across all waveforms position it as an optimal choice for EV infrastructure. The Boost, Interleaved and Z-Source converters, while viable in specific contexts, fall short in balancing efficiency and speed, as their waveforms indicate higher variability and slower SOC progression. The Quasi-Z-Source's performance across varying voltages and battery types further underscores its robustness, offering a scalable solution for future EV charger designs.

## VI. Conclusion

This study explores the technical design elements of an electric vehicle (EV) charging station aimed at fulfilling transportation demands. The charging converters are meticulously crafted to ensure sufficient battery charge delivery for EVs. The charger architecture features a three-phase full-bridge rectifier that elevates the grid voltage to the desired level, coupled with DC-DC converters to charge the batteries effectively. To evaluate this EV charging system and its battery interactions, a MATLAB/Simulink model was constructed, allowing precise control and simulation of the proposed configuration. Upon conducting simulations with various converter types, the Quasi-Z-Source converter demonstrated a faster charging time, achieving 20% to 80% SOC in 1.35 hours, surpassing the Z-Source converter, interleaved converter and the Boost converter. The results from this model indicate that the proposed design adeptly addresses the population's transportation requirements by optimizing charging efficiency and speed based on input analysis. The Quasi-Z-Source converter's standout performance positions it as a promising solution for enhancing EV charging stations, contributing significantly to the infrastructure supporting electric mobility.

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